

ether (b. p. 60–110°); white crystals, m. p. 124–125° (corr.). It gives a green color with ferric chloride.

Anal. Calcd. for $C_{16}H_{12}O_4$: C, 61.22; H, 6.13. Found: C, 61.27; H, 5.87.

Summary

1. The synthesis of 1,2-dimethoxy-3-isopropyl-4-benzoic acid was accomplished by brominating 1-methoxy-2-acetoxy-3-isopropylbenzene to 1-methoxy-2-acetoxy-3-isopropyl-4-bromobenzene. Saponification of the acetyl group and methylation gave 1,2-dimethoxy-3-isopropyl-4-bromobenzene which through the Grignard reagent and carbon dioxide gave the product desired.

2. This acid upon nitration gave 1,2-dimethoxy-3-isopropyl-5-nitro-4-benzoic acid, which was identical with the substance obtained by nitrating

apogossypolic acid. The methyl esters were also identical.

3. The methyl 1,2-dimethoxy-3-isopropyl-5-nitro-4-benzoate upon reduction to the corresponding amine, diazotization and replacement with a cyanide group and subsequent hydrolysis gave 1,2-dimethoxy-3-isopropyl-4,5-dicarboxybenzene, identical with apogossypolic acid.

4. The established structure of apogossypolic acid fixes the structure of gossic acid and thus indicates that the aldehyde groups in the gossypol molecule are para to the isopropyl groups. The character of the substituents in the 1-, 5-, 6-, 7- and 8-positions of the naphthalene nuclei of gossypol is thus verified.

URBANA, ILLINOIS

RECEIVED MARCH 6, 1939

[CONTRIBUTION FROM THE HENRY BAIRD FAVILL LABORATORY OF ST. LUKE'S HOSPITAL AND THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF CHICAGO]

A Study of the Methods of Separation of Oleic Acid from Saturated Acids and Linoleic Acid with Observations on the Preparation of Oleic Acid

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Several methods for the preparation of "pure" oleic acid have been reviewed by Brown and Shinowara.² The purity of the product obtained was calculated from the iodine and acid numbers and the melting point. These estimations in the presence of nearly equal amounts of saturated and linoleic acids do not demonstrate a purity exceeding 95%. Kaufmann³ improved the methods for estimating the components in mixtures of fatty acids by making determinations of both the iodine and the thiocyanogen numbers. Others have modified the Kaufmann procedure.⁴ In my investigations the procedure recommended by Irwin, *et al.*,^{4d} was used. The maximum purity of an oleic acid preparation purified by several methods was 97.8%.

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(2) J. B. Brown and G. Y. Shinowara, *THIS JOURNAL*, **59**, 6 (1937).

(3) (a) H. P. Kaufmann, *Arch. Pharm.*, **263**, 675 (1925); (b) H. P. Kaufmann, *Z. Untersuch. Lebensm.*, **51**, 15 (1926); (c) H. P. Kaufmann, *Z. angew. Chem.*, **41**, 19 (1928); (d) H. P. Kaufmann and M. Keller, *ibid.*, **42**, 20, 73 (1929).

(4) (a) G. S. Jamieson and W. F. Baughman, *Oil & Fat Industries*, **7**, 419, 437 (1930); (b) W. S. Martin and R. C. Stillman, *Oil & Soap*, **10**, 29 (1933) (gives many references to earlier articles); (c) H. N. Griffiths and T. P. Hilditch, *J. Soc. Chem. Ind.*, **53**, 75T (1934); (d) W. H. Irwin, *et al.*, *Ind. Eng. Chem., Anal. Ed.*, **8**, 233 (1936).

Experimental

The Separation of Saturated from Unsaturated Fatty Acids.—The method of Brown and Shinowara² was found to be the most efficient method for the separation of saturated from unsaturated fatty acids. Fifty grams of the mixed fatty acids of olive oil or of teaseed oil was dissolved in 500 ml. of acetone. The solution was cooled to -18 to -20° for four or five hours. The saturated acids which precipitated were separated from the solution by filtration on a jacketed Büchner funnel, cooled to -14° . In one experiment, a 50-g. sample of mixed fatty acids, of iodine no. 90.05, containing about 10.5% each of saturated acids and linoleic acid, was divided into a 5.3-g. precipitate of iodine no. 4.8, and a 44.0-g. filtrate of iodine no. 99.9. Only 1.0% of the saturated acids remained in the filtrate.

Three other methods were investigated for the separation of saturated acids from unsaturated fatty acids. The only one of these which compared favorably with the method of Brown and Shinowara was a recent modification of the Twitchell lead soap-alcohol method.^{4d} When a 50-g. sample of mixed fatty acids was separated by this method, the fatty acids recovered from the precipitate weighed 7.1 g. and had an iodine no. of 34.8, while the fatty acids recovered from the filtrate weighed 35.9 g. and had an iodine no. of 100.6. Only 1.0% of the fatty acids of the filtrate was saturated acids. However, the yield is not as great as with the Brown and Shinowara method, more oleic acid being lost with the precipitate, and more material being lost in transferring the sticky lead soaps from one container to another.

TABLE I

Sample	Pb acetate used, g.	Product, g.	Iodine no.	Mean mol. wt.	Approx. % linoleic removed	Approx. % oleic	General method
Ppt. K	12.73	16.6	87.5	281.9	89.0	88.7	Pb soap
Filt. K		21.8	111.5	293.8			
Ppt. L	19.10	26.2	90.0	282.7	79.8	89.8	Pb soap
Filt. L		14.5	120.5	299.1			
Ppt. M	25.46	34.1	92.0	282.8	58.7	88.2	Pb soap
Filt. M		6.5	140.3	321.9			
Ppt. N	14.35 (Ba(OH) ₂)	19.9	92.5	282.1	77.3	86.3	Ba soap
Filt. N		22.4	109.9	298.1			
Ppt. O	...	25.7	87.6	282.8	95.0	94.1	(-60° acetone)
Filt. O ₁		15.2	144.6	316.5			
Filt. O ₂		3.5	119.8	294.1			
Filt. O ₃		4.9	92.5	...			
Filt. O ₄		2.1	89.0	285.1			

The amount and the iodine no. of the precipitate of "saturated" acids obtained by the Twitchell method depended upon the amount of lead acetate used as a precipitant. A quantity of mixed fatty acids from olive oil was divided into five 90-g. portions and each portion was dissolved in 900 cc. of 95% alcohol. Amounts of lead acetate from 15 to 50 g. were added to each portion and heated until dissolved. The solutions were then kept at 15° overnight, filtered on a cold Büchner funnel and the lead soaps of the precipitate and filtrate decomposed with dilute hydrochloric acid to recover the free fatty acids. The weight of fatty acids recovered from the precipitates varied from 20.7 g. in the sample to which 15 g. of lead acetate was added, to 59.5 g. in the sample to which 50 g. of lead acetate was added. The corresponding iodine nos. varied from 48.8 to 77.7. These results contradict statements in the literature that the lead soaps of the unsaturated acids are soluble in 95% alcohol at 15°. The weight of fatty acids recovered from the precipitate was nearly equivalent to the amount of lead acetate used, after allowance had been made for material lost. Most of the saturated acids precipitated first. The excess lead acetate then precipitated part of the unsaturated fatty acids, principally oleic acid. Similar results were obtained by Keffler and McLean⁵ when they attempted to remove the saturated fatty acids from a sample of oleic acid containing about 4% of saturated acids. They added enough lead acetate to react with 24% of the total weight of fatty acids and obtained a precipitate of "saturated acids" which amounted to 22.5% of the total weight of fatty acids and had an iodine no. of 85.7.

Separation of Oleic Acid from Linoleic Acid.—The following methods for the separation of oleic acid from linoleic acid were tried: (a) distillation of the mixed fatty acids under a low pressure, (b) cooling to -15 to -25° of the mixed fatty acids diluted with an equal volume of 95% alcohol, (c) three crystallizations of the mixed barium soaps,⁷ (d) a lead soap-alcohol method and (e) four crystallizations of the mixed fatty acids from acetone.² Of these methods, procedure (e) proved to be

the best, and was used subsequently in the preparation of the purest oleic acid sample.

The distillation method (a) gave almost no separation of oleic acid from linoleic acid, and method (b) also gave poor separations. Methods (c), (d), and (e) were then compared, using a mixture of fatty acids of iodine no. 100.9 and a mean molecular weight of 287.7. Part of the saturated acids had been removed from this sample. The following procedures were used to obtain the data collected in Table I.

Method (c).—To 45 g. sample N enough barium hydroxide was added to combine with all the fatty acids in the sample. The barium soaps obtained were crystallized three times from 450-cc. portions of a mixture of equal volumes of absolute alcohol and benzene. The fatty acids were recovered from the precipitate and the combined filtrates by decomposition of the barium soaps with dilute hydrochloric acid, washing with water to remove acid, and heating to 70° to expel the benzene.

Method (d).—This method was based on the assumption that lead acetate added to a mixture of fatty acids in 95% alcohol would precipitate first the saturated acids, then the oleic acid and finally the linoleic. Only enough lead acetate was added to the 45-g. samples K, L, and M to precipitate the saturated acids and half, three quarters, and all, respectively, of the oleic acid present. The lead soaps were formed in 450 cc. of hot 95% alcohol, cooled to -15° for two to three hours, and filtered on a Büchner funnel cooled to about -13°. The lead soaps of the precipitates and filtrates were decomposed with dilute hydrochloric acid in a manner similar to the treatment of the barium soaps.

Method (e).—Seventy-gram sample O was crystallized four times at -60°, first from 700 cc. of acetone and subsequently from a volume of acetone ten times as great as the weight of the fatty acid precipitate obtained from the previous crystallization. The acetone was distilled from each filtrate under reduced pressure, leaving the fatty acid filtrates O₁, O₂, O₃, and O₄. The fatty acids from the fourth crystallization at -60° melted at room temperature to give "Ppt. O" of Table I.

The results in Table I demonstrate clearly that the -60° acetone method is the best of these three methods. Approximately 95% of the linoleic acid was removed, and a product was obtained containing about 94% oleic acid.

(5) L. Keffler and J. H. McLean, *J. Soc. Chem. Ind.*, **54**, 362-7 (1935).

(6) E. Raymond, *Chimie & industrie*, Special No., Feb., 1929, p. 523.

(7) J. H. Skellon, *J. Soc. Chem. Ind.*, **50**, 131T (1931).

Of the other two methods, one crystallization of the fatty acids using a calculated amount of lead acetate is superior to three crystallizations of the barium soaps of the fatty acids.

The final method adopted for the separation of oleic acid from linoleic acid involved an initial crystallization of oleic acid from 10 volumes of acetone at -60° . By this crystallization a considerable amount of linoleic acid was separated. Consequently, for the last three crystallizations, only five volumes of acetone were used, and the crystallizations were carried out at -40° instead of -60° . This resulted in a 10% increase in the yield of precipitate, without decreasing the efficiency of the separation of the residual linoleic acid. It also helped to reduce the percentage of saturated acids in the oleic acid precipitate, by increasing the ratio of oleic acid to saturated acids.

Removal of the Remaining Saturated Acids.—Three samples of fatty acids from which much of the saturated acids had been removed by the -20° acetone method and from which most of the linoleic had been removed by crystallizations from acetone at -60 and -40° as described above, had iodine nos. varying from 86.7 to 87.1 (theoretical for oleic acid, 89.87). This indicated that the samples still contained saturated acids. Part of these were removed by a lead soap precipitation in 95% alcohol, using three times as much lead acetate as the amount required to react with the estimated amount of saturated acids. At this stage of the purification process, the lead soap method was better than the -20° acetone method, but not over 20% of the saturated acids were removed. The iodine nos. of the resulting product were raised slightly, to 87.1 to 87.3. Thiocyanogen no. analyses indicated that the samples contained from 4.1 to 4.5% saturated acids, 1.0 to 1.6% linoleic acid, and 93.9 to 95.0% oleic acid.

In order to remove more of the saturated acids, these samples were combined and distilled at about 1 mm. pressure in a still with an electrically heated glass column four feet (1.2 meters) high and one inch (2.5 cm.) inside diameter, filled with glass helices. The helices were approximately 5 mm. in outside diameter.⁸ The temperature of the still head also was controlled electrically to maintain the reflux ratio between 5:1 and 10:1. A small amount of a yellow liquid distilled first, followed by a small amount of a semi-solid (saturated acids, contaminated with oleic acid). Succeeding fractions were colorless liquids, and contained decreasing percentages of saturated acids, as calculated from iodine and thiocyanogen no. analyses. Data on these liquid fractions are collected in

Table II. The sixth fraction represented the purest oleic acid. It contained 97.8% oleic acid, 1.0% linoleic acid and 1.2% saturated acids.

TABLE II

No.	G.	I no.	Thio. no.	% oleic	% lin-oleic	% satd.
1	30.6	86.84	85.88	94.5	1.1	4.4
2	33.0	87.42	86.28	94.7	1.3	4.0
3	48.0	87.97	86.62	94.9	1.5	3.6
4	27.1	87.74	86.82	95.6	1.0	3.4
5	30.4	88.19	87.52	96.7	0.7	2.6
6	31.2	89.71	88.82	97.8	1.0	1.2
7	15.9	84.39	83.26

Discussion

The -20° acetone method is better than the lead soap-alcohol method which has been used by most previous investigators for the separation of saturated from unsaturated fatty acids, and the modified -60° acetone method is superior to the other methods tried for the separation of oleic acid from linoleic acid, yet these procedures yielded a product containing less than 96% oleic acid, based on iodine no. and thiocyanogen no. analyses. Therefore it is probable that pure oleic acid has never been prepared. Probably 97 to 98% purity represents the maximum obtainable by present methods.

Summary

Various methods for the purification of oleic acid were compared as to efficiency of separation from saturated acids and from linoleic acid. A scheme was devised, consisting of crystallizations from acetone at -20 , -60 , and -40° , followed by a precipitation of part of the remaining saturated acids as lead soaps in alcohol, and finally a fractional distillation at 1 mm. pressure, which yielded a sample of oleic acid 97.8% pure, as determined by iodine no. and thiocyanogen no. analyses. This probably represents as pure a sample of oleic acid as has thus far been obtained.

(8) C. D. Wilson, G. T. Parker and K. C. Laughlin, *THIS JOURNAL*, **55**, 2795 (1933).